# Widely tunable narrow-band terahertz-wave source pumped by injection-seeded optical parametric generation

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**Abstract:** We proposed a novel widely tunable terahertz-wave source pumped by injection-seeded KTP optical parametric generator. Efficient narrowing of line-width and high output of the pump source were obtained to 50 GHz and 273 μJ respectively.
**OCIS codes:** (140.3580) Lasers, solid-state; (190.4410) Nonlinear optics, parametric processes;

## 1. Introduction

The developments of coherent monochromatic terahertz(THz)-wave sources with high power, wide frequency-tunability and narrow spectrum line-width are essential to accelerate various THz researches and applications. In particular, high power THz-wave radiation with narrow spectrum line-width has attracted much interest in molecular science [1], since intense THz waves interact non-thermally with molecular bonding networks as exciting or cutting them. Additionally, the wide tunability can access to different absorption peak of various materials.

In order to generate monochromatic THz waves with ultra-wideband tunability, organic nonlinear optical crystals have been employed in difference frequency generation (DFG). In particular, a 4-dimethylamino-N-methyl-4-stilbazolium-tosylate (DAST) crystal is promising for ultra-wideband THz-wave generation. We have developed the powerful DAST-DFG THz-wave source pumped by KTP optical parametric oscillator (OPO) [2,3].

In this report, to obtain the high output THz waves with narrow spectrum line-width, we propose novel DAST-DFG THz-wave source pumped by an injection-seeded optical parametric generator (OPG) with KTP crystals. In the first stage of establishment of the THz-wave source, we demonstrated an injection-seeded KTP-OPG pump source. Injection-seeding technique is an effective method for narrowing spectrum line-width [4].

## 2. Experiments

Figure 1 shows the experimental setup for injection seeded optical parametric generation using KTP crystals. Second harmonic of a Q-switched multimode Nd:YAG laser (532 nm, 60 mJ/pulse, 10 ns and 100 Hz) was used as the pump source for the KTP-OPG. External cavity diode lasers (ECDL: 6 mW, CW) was used as seed laser with tunable range from 1270 to 1330 nm. The seed laser was amplified by semiconductor optical amplifier (SOA) up to 60 mW. The spectrum line-width of amplified seed laser was 0.05 nm using optical spectrum analyzer with the resolution of 0.01 nm. The pump and seed laser beams were relayed by using dichroic mirror ($DM_1$:HT@532 nm, HR@1250-1650 nm). The diameters of the pump and seed laser beam to the KTP crystal was 3 mm. The KTP crystal had dimensions of 5 x 10 x 27 $mm^3$. The crystal surface were AR-coated for pump, signal and idler wavelength (532nm, 750-1000nm, 1250-1650nm), respectively. The KTP crystal was mounted on a galvano-optical beam scanner and the phase matching angle can be controlled. In order to the output wavelengths from the OPG were collinearly, the idler was separated by $DM_2$ (HR@532 nm, HR@700-1000nm, HT@1250-1650 nm).

Figure 2 shows the spectra of idler $\lambda_1$ with and without seed laser, respectively. The wavelength of seed laser was adjusted at 1306 nm. The seed laser power was 60 mW. The pump power was fixed at 40 mJ/pulse which was corresponding to the power density of ~56 $MW/cm^2$. The spectrum line-width could be reduced down to 50 GHz by injection-seeding. The spectrum line-width with seeding was drastically 7 times narrower than that without seeding.

Figure 3 shows the measured output energy of idler $\lambda_1$ from the OPG as a function of the pump energy. The idler energy was almost proportional to the pump energy with the threshold energy of 19 mJ. Then output saturation was not apparent. The maximum output energy of idler $\lambda_1$ was obtained 237 uJ/pulse at the seed laser power of 60 mW and the pump energy of 40 mJ. The output energy of the idler was approximately 26 times higher than that without injection-seeding.

## 3. Conclusions

We proposed narrow-band injection-seeded optical parametric generation for pump source of DAST-DFG THz-wave source. The maximum energy of the idler $\lambda_1$ was achieved 237 uJ at the seeding laser power of 60 mW and the pump energy of 40 mJ. It was 26 times higher than that without seeding laser. Additionally the spectrum line-width

of the idler was reduced down to 50 GHz. That value was 7 times narrower than that without seed laser.

Power scaling up to few mJ of the OPG system is possible by increasing the pump power of KTP crystals and cascading the KTP crystals. The wavelength of the idler can control by ECLD and phase matching angle of KTP crystal electrically. The OPG system will generate THz-wave with the tunable range of 1-10 THz.

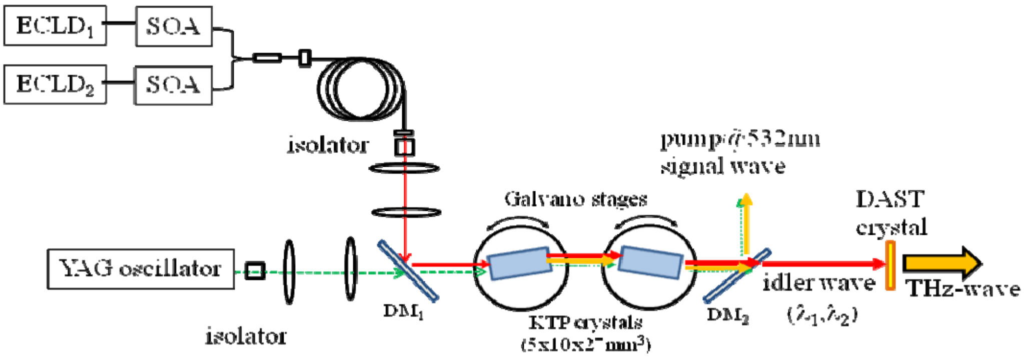


Fig. 1. Schematic diagram of tunable THz source based on KTP-OPG.

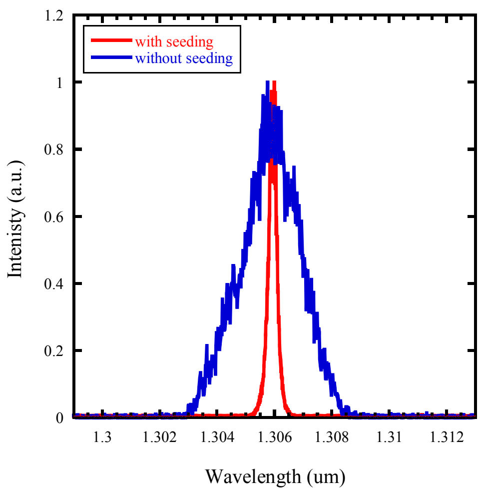


Fig. 2. Spectra from the pump source with and without seeding.

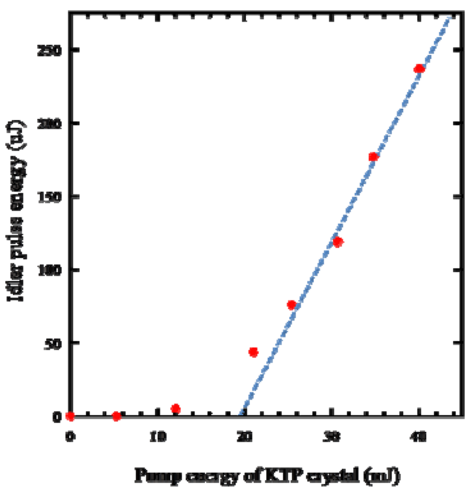


Fig. 3. Output energy from the OPG as a function of pump energy.

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## 4. Reference

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